

## MiniBooNE: Studying the elusive neutrino

Ever since the 1950s, when the neutrino was first observed by scientists at Los Alamos National Laboratory, physicists have sought out this elusive subatomic particle for what it could reveal about the nature of the universe.

Every second, billions of neutrinos, originating in the Sun, pass through each person on Earth. Yet, as their name suggests, neutrinos are neutral—not carrying an electric charge—and therefore rarely interact with any other matter, making their detection, even by highly sophisticated instruments, challenging.

As pioneers in the search for neutrino signatures, Los Alamos physicists designed MiniBooNE (for Mini Booster Neutrino Experiment) as a follow-on to the LSND (Liquid Scintillator Neutrino Detector) experiment at Los Alamos.

Located at Fermilab, MiniBooNE searched for new and exotic types of neutrinos, over the distance of half a kilometer. Using neutrinos created by an accelerator and an 800-ton tank filled with pure mineral oil and extremely sensitive light sensors, Los Alamos scientists helped to construct and operate the MiniBooNE experiment over the past decade.

The U.S. Department of Energy and the U.S. National Science Foundation fund the work of MiniBooNE physicists, who are part of a collaboration of 16 institutions from the United States and Mexico.

## Technical feats and milestones

**1993:** the year that the first beam-induced neutrino was observed by LSND

**1995:** the year Los Alamos's LSND experiment reported first results that provided evidence for neutrino oscillations, the transmutation of muon anti-neutrinos into electron anti-neutrinos, and suggested that neutrinos have mass

**2002:** the year that the first beam-induced neutrino was observed by MiniBooNE, which was designed to test the LSND oscillation signal

**2010:** the year MiniBooNE reported results consistent with the LSND oscillation signal, suggesting that muon anti-neutrinos transform into electron anti-neutrinos and that additional sterile neutrinos exist in nature



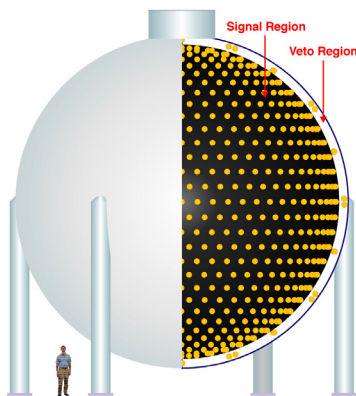
The MiniBooNE experiment relies on a large tank filled with mineral oil, which is clearer than water from a faucet. Photomultiplier tubes mounted inside the tank are capable of detecting collisions between neutrinos and carbon nuclei of oil molecules.

There are 1,280 extremely sensitive light sensors, called photomultiplier tubes, lining the inside of the MiniBooNE tank.

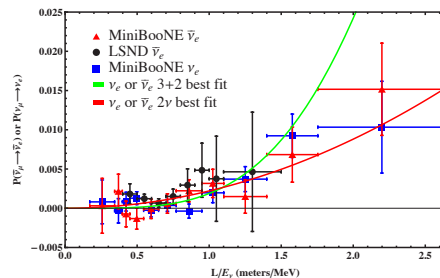


**250k**

The number of gallons of clear mineral oil in the MiniBooNE detector.



This illustration of the MiniBooNE tank shows the inner layer of the 1,280 photomultiplier tubes that detect neutrinos produced by Fermilab's Booster accelerator. A second layer of 240 photomultiplier tubes, still inside the tank, but facing outward, detects signals caused by cosmic ray showers.



Comparison of the MiniBooNE and LSND oscillation signals as a function of  $L/E$  (where  $L$  is the neutrino energy and  $E$  is neutrino energy).

*Los Alamos National Laboratory scientists and engineers lead efforts to discover new physics by performing precise measurements of nuclear physics processes.*

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## MAJORANA: A detector to illuminate the nature of the universe

In the quest to understand how matter evolved, Los Alamos scientists and collaborators are constructing the MAJORANA DEMONSTRATOR, a sensitive detector prototype that aims to detect the rare signal of neutrinoless double-beta decay.

This experimental technique is the only practical method to determine whether or not the neutrino is its own anti-particle. The answer to this important question may help us understand why the universe is mostly matter with almost no anti-matter and therefore how we came to exist.

Searching for such a rarely observed phenomenon requires unprecedented low background radiation levels and must be done under extremely clean conditions to avoid the naturally occurring radioactivity ubiquitous in common materials, dust, and human fingerprints.

During the MAJORANA DEMONSTRATOR'S construction, Los Alamos physicists are lending their expertise in ultrasensitive particle detection and radiation shielding for extremely low-background radiation experiments taking place at a South Dakota underground laboratory. As part of the leadership of the international MAJORANA collaboration, the Los Alamos team will help operate the four-year experiment and analyze the data. The Laboratory Directed Research and Development program at Los Alamos helped develop the project design, which led to DOE funding for the project itself.

With success, the MAJORANA DEMONSTRATOR will lead to a much larger international experiment with even greater sensitivity – and in time the fundamental nature of the universe may become less of a mystery.

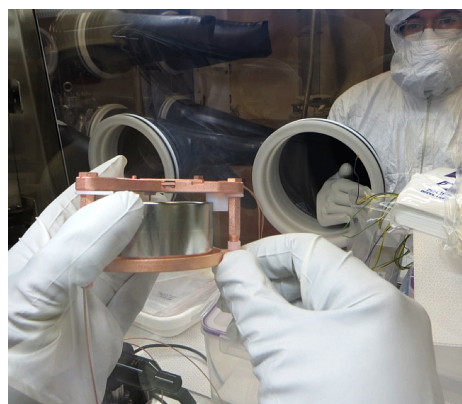


**2 cryostats** will house the detectors and be operated inside a large shield fabricated from copper, lead, and plastic.

**4,850<sup>ft</sup>**

The depth at which the MAJORANA is located, to avoid exposure to the cosmic rays prevalent on the Earth's surface.

**19** The number of international institutions involved in the MAJORANA experiment from 5 countries; USA, Japan, Canada, Russia, and China.



**30 kg** of detectors made from germanium enriched in isotope 76. The detector shown weighs about 600 grams and is made from natural germanium. Los Alamos National Laboratory postdoctoral researcher Johnny Goett is shown helping assemble the detector unit.



**5,000 lbs** of copper is electroformed and machined underground to eliminate long-lived radioactivity produced on the Earth's surface by cosmic rays.

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